

APPENDIX E
SOURCE ASSESSMENT AND LOADING ANALYSIS

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The information contained in the Source Assessment & Loading Summary provides data that aids the development of a generalized gross allocation strategy for the watershed. The results of the analysis exhibit exceedances at both high and low flow, and provide evidence that metals concentrations do increase in a downstream direction at some locations. This analysis is helpful in developing future monitoring efforts to further characterize and localize the metals inputs to Prospect Creek and its tributaries.

E.1 Source Assessment Results

As mentioned above, the exceedances are most frequent for antimony under both high and low flow conditions. Exceedances for other metals (arsenic, lead, and zinc) are less frequent, and are always accompanied by exceedances for antimony. Therefore, the metals loading analysis for the Prospect Creek watershed was conducted using antimony as a representative constituent. This analysis is done under both high and low flow conditions since different mechanisms for metals transport conditions can be occurring as a function of flow conditions, and the spatial distribution of metals loading sources may vary with stream flow conditions. This approach helps to ensure that water quality standards will be satisfied during both high and low flow conditions, and that the TMDL adequately accounts for seasonality-related trends.

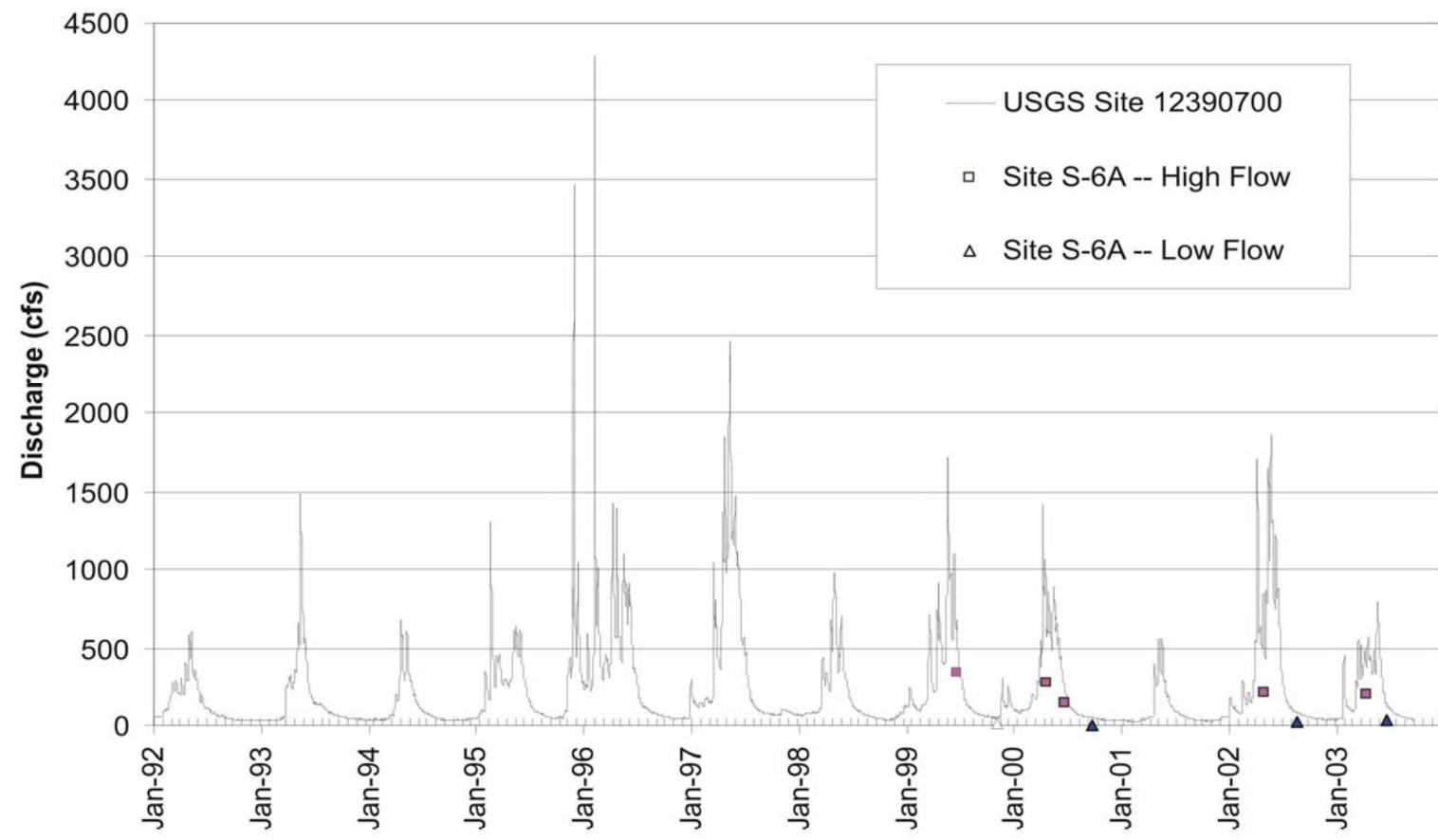
Figure 3-1 shows abandoned mines in the Prospect Creek watershed (shown by the diamonds), as identified in the Montana Bureau of Mines and Geology abandoned and inactive mine database available from the Montana Natural Resources Information System (NRIS), and the USAC milling and metallurgical facilities near the mouth of Cox Gulch. Abandoned mines and associated mine waste material, and the USAC facility constitute potential sources of metals impairment in the Prospect Creek watershed, along with possible natural background loading. The USAC tailings impoundment was previously identified as a source of antimony contamination in shallow ground water and surface waters in the vicinity of the facility (Woessner and Shapley, 1985), although that was prior to reclamation of the three tailings impoundments in the late 1990s.

Specific sources associated with abandoned mines may include discrete mine waste or tailings piles, fluvial mine waste located along the floodplain or within stream channels, and discharging adits. Other potential sources include metals-bearing ground water (either natural or mining-related), and natural erosion or metals leaching from exposed mineralized bedrock. Specific sources associated with the USAC operation may include mine adits and/or mine waste material associated with USAC's mining operations, storm water runoff from the milling and metallurgical facility, and leaching of materials from waste materials stored in the tailings impoundments.

In order to determine the most likely sources of metals loading in the Prospect Creek watershed, plots of antimony load in lb/day vs. streamflow were constructed for each of the three listed stream segments to evaluate the data for any general correlation between flow and metals loading (Figures 3-2, 3-4 and 3-5). As shown on Figures 3-2, 3-4, and 3-5, antimony loads generally

increase with increasing flow in each of the stream segments. Increasing loads with increasing flow could result from erosion or leaching of metals from mine waste piles, or increased recharge to the streams from metals-bearing ground water under high flow conditions. More detailed water quality sampling, an improved understanding of ground water flow patterns, and/or comparison of total recoverable to dissolved metals concentrations in surface waters would aid in further definition of seasonal metals loading sources in the watershed. Regardless of the specific source types, water quality standard exceedances for antimony, and occasionally arsenic, lead and zinc, are observed under both high and low flow conditions.

Based on the available flow and water quality data, a representative set of monitoring events were examined in detail to evaluate high and low flow metals loading trends and potential source areas. Definition of high and low flow periods in the Prospect Creek watershed was determined by comparing individual flow measurements from site S-6A reported in the USAC dataset and by inspection of with the continuous flow hydrograph for Prospect Creek obtained from the USGS gage installed at the mouth of Prospect Creek (Figure E-1). As shown in the figure, the S-6A instantaneous flow measurements from the defined high flow and low flow periods correspond to the high flow and low flow portions of the continuous flow hydrograph. This indicates that the definition of water quality data collected between April through June as high flow data, and data collected from all other times of the year as low flow data, is an appropriate approximation.



Prospect Creek Discharge at
USGS Gaging Site and
Sampling Site SW-6A

FIGURE
E-1

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Figure E-1. Prospect Creek Discharge at USGS Gaging Site and Sampling Site SW-6A.

E.2 Load Assessment Results

E.2.1 Antimony Creek Loading

Figure E-2 presents the antimony load with respect to flow for those sampling events included in analysis of Antimony Creek. The antimony load is compared to the TMDL for given flow conditions. Table E-1 displays a representative set of high flow and low flow monitoring events for Antimony Creek. Observations and analysis of the data for Antimony Creek follows Table E-1.

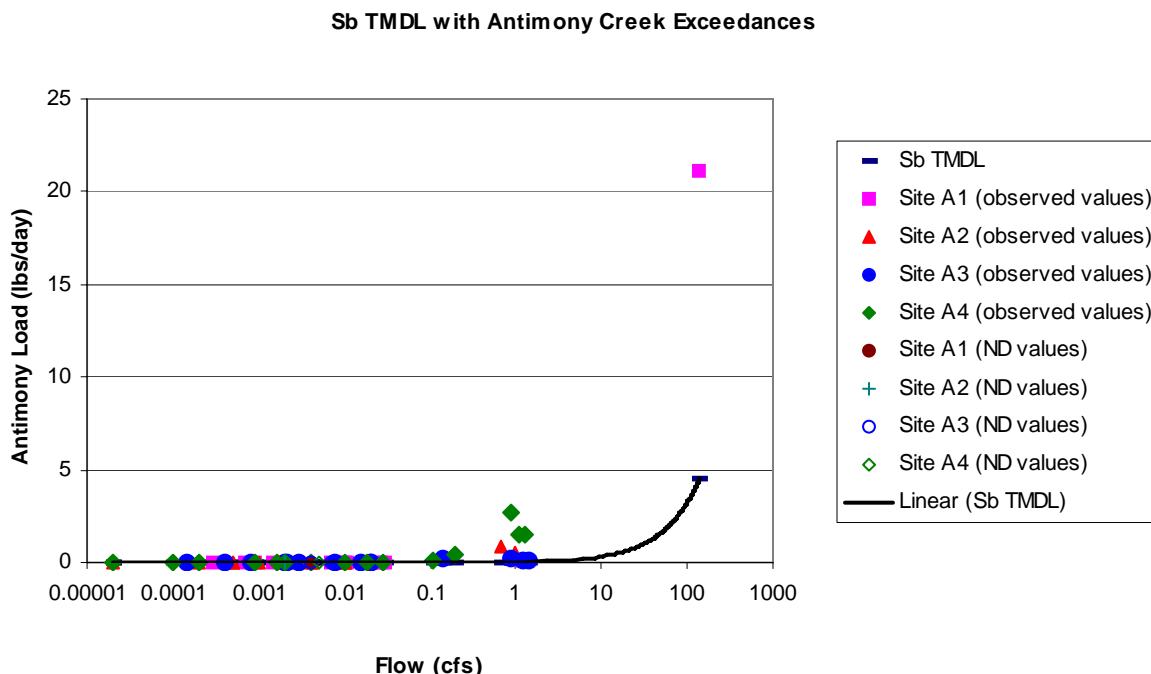


Figure E-2. Sb TMDL with Antimony Creek Exceedances.

Table E-1. Antimony Creek High and Low Flow Monitoring Data.

| High Flow Monitoring Date | | | | | | | | | |
|---------------------------|------------|---------------|-------------------|------------|---------------|-------------------|------------|---------------|-------------------|
| | 6/25/99 | | | 4/26/00 | | | 6/29/00 | | |
| Site | Flow (cfs) | Concentration | Sb Load (lbs/day) | Flow (cfs) | Concentration | Sb Load (lbs/day) | Flow (cfs) | Concentration | Sb Load (lbs/day) |
| A-1 | .011 | 37 | .0022 | 1.2 | 20 | .129 | .007 | 19 | .0007 |
| A-3 | .0021 | 15 | .0002 | 1.45 | 14 | .109 | .016 | 462 | .0399 |
| A-2 | .00438 | 12 | .0003 | .667 | 230 | .827 | .004 | 614 | .013 |
| A-4 | .00167 | 257 | .0023 | 1.12 | 245 | 1.48 | .01 | 16 | .0009 |
| | 5/9/02 | | | 4/23/03 | | | | | |
| A-1 | .027 | 17 | .002 | 140* | 28 | 21.14 | | | |
| A-3 | .14 | 238 | .18 | .02 | 14 | .002 | | | |
| A-2 | .017 | 229 | .021 | .01 | 400 | .022 | | | |

Table E-1. Antimony Creek High and Low Flow Monitoring Data.

| | | | | | | |
|---------------------------------|-----------------|---------------|----------------------|---------------|---------------|----------------------|
| A-4 | .11 | 248 | .147 | .018 | 428 | .042 |
| Low Flow Monitoring Date | | | | | | |
| | 11/12/99 | | 9/29/00 | | | |
| Site | Flow (cfs) | Concentration | Sb Load (lbs/day) | Flow (cfs) | Concentration | Sb Load (lbs/day) |
| A-1 | .004 | <3 | <.00006 | .002 | 26 | .0003 |
| A-3 | .007 | <3 | <.00011 | .003 | 17 | .0003 |
| A-2 | .002 | <3 | <.00003 | .002 | 846 | .0091 |
| A-4 | .005 | <3 | <.00008 | .002 | 458 | .0049 |
| | 8/29/02 | | 6/29/03 | | | |
| A-1 | .0007 | 32 | .00012 | ND | ND | ND |
| A-3 | .0008 | 14 | .00006 | .002 | 9 | .0001 |
| A-2 | .0005 | 1060 | .0029 | .001 | 850 | .0046 |
| A-4 | .0009 | 622 | .003 | ND | 525 | NC |

NOTES: *Reported value, probably an error.

ND = no data.

NC = not calculated.

Bold values indicate antimony concentrations exceeded water quality criteria for the given location.

The relatively low flow conditions in these two streams may add additional uncertainty to this analysis, particularly during the lower flow period when some measures flows are as low as 1 gallon per minute. The extremely low cfs values presented are a result of the conversion of field data to comparable units, e.g. gallons per minute to cubic feet per second.

- During high flow, antimony loads typically increase through the upper portion of the east and west forks of Antimony Creek (from A-1 to A-3, and from A-2 to A-4), with load increases more consistent in the west fork. Concentrations exceed water quality standards at the upstream sites A-1 and A-2, as well as the downstream sites A-3 and A-4. Thus, the data indicate the existence of one or more metals loading sources in the east and west forks of Antimony Creek, above sites A-1 and A-2 and between sites A-1/A-3 and A-2/A-4 during high flow conditions. It is possible that most or all of the metals load originates in the upper portions of the watershed above sites A-1 and A-2 and that some of this load is carried via subsurface flow and enters Antimony Creek between sites A-1/A-3 and A-2/A-4. Additional data would be necessary to make such a determination.
- For low flow, the data indicate the existing of one or more metals loading sources upstream of sites A-1 and A-3, but not between the upstream and downstream sites as indicated during the high flow period.
- Based on review of USGS topographic maps, aerial photos, and land use information, the most likely metals loading sources in Antimony Creek drainage include abandoned mines and natural background sources. Mining-related sources may include mine waste rock piles, discharging adits, or leaching of metals to ground water from underground mine workings. Background loading sources may include naturally mineralized ground

water or erosion of exposed mineralized bedrock. Resuspension of metals-bearing stream sediments during higher flows (derived either from natural or mining-related sources) are another potential metals loading source in Antimony Creek.

E.2.2 Cox Gulch Loading

Figure E-3 presents the Antimony load with respect to flow for those sampling events included in analysis of Cox Gulch. The Antimony load is compared to the TMDL for given flow conditions. As there is only one sampling location used for Cox Gulch, representative high flow and low flow data is included with the data for Prospect Creek (Table E-2). Observations and analysis of the data for Cox Gulch follows Figure E-3.

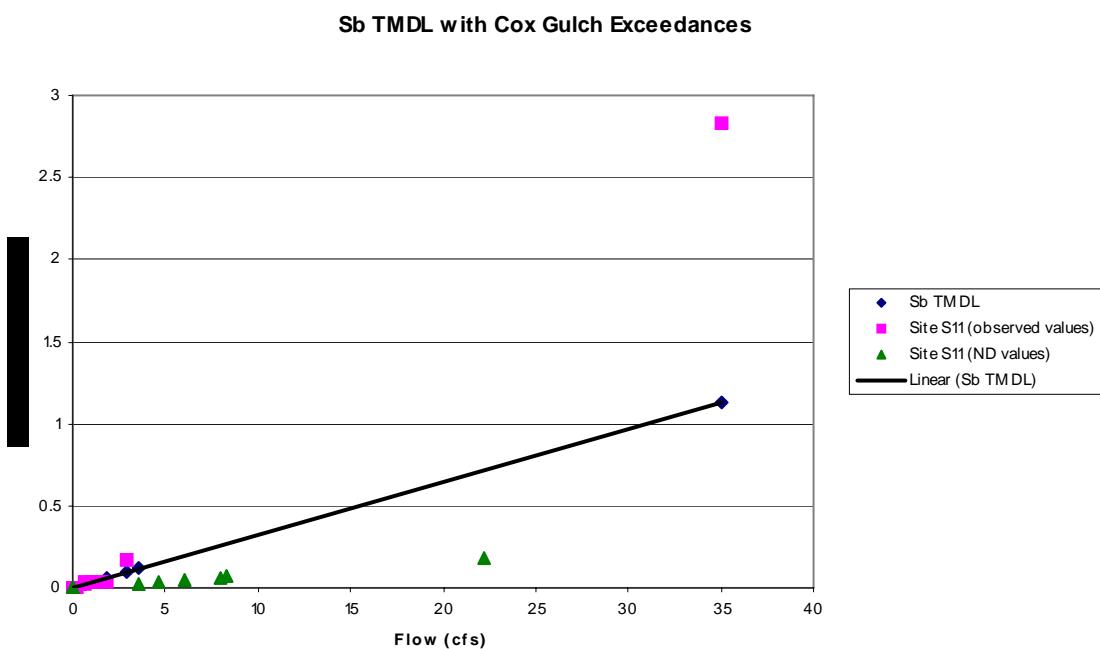


Figure E-3. Sb TMDL with Cox Gulch Exceedances.

- Only one monitoring site in Cox Gulch (S-11), located upstream of the USAC mill and tailings facility, has been sampled on a regular basis. Water quality exceedances for antimony are infrequent, but have been observed occasionally (Tables 3-2 through 3-4) during both low and high flows, along with one exceedance for lead during a relatively high flow (8 cfs). The limited data for this sample site suggests an increase in antimony loading as flow increases.
- The upper portion of Cox Gulch (upstream of site S-11) includes one or more source areas for antimony. Based on review of site maps and aerial photographs, potential sources include mine facilities, recharge from mineralized ground water (either natural or mining-related), and/or instream sources related to remobilization of previously precipitated metals.

As discussed in the introduction to this section, a number of water quality samples collected between 1995 and 1997 from site S-11 showed elevated lead and zinc concentrations on the order of 2 to 7 mg/L (100 to 1000 times the standard). However, this data was found to be erroneous and was not used in the Cox Gulch impairment determination or in the metals loading source assessment.

E.2.3 Prospect Creek Loading

Figure E-4 presents the Antimony load with respect to flow for those sampling events included in analysis of Prospect Creek. The Antimony load is compared to the TMDL for given flow conditions. Table E-2 displays a representative set of high flow and low flow monitoring events for Prospect Creek. Observations and analysis of the data for Prospect Creek follows Table E-2.

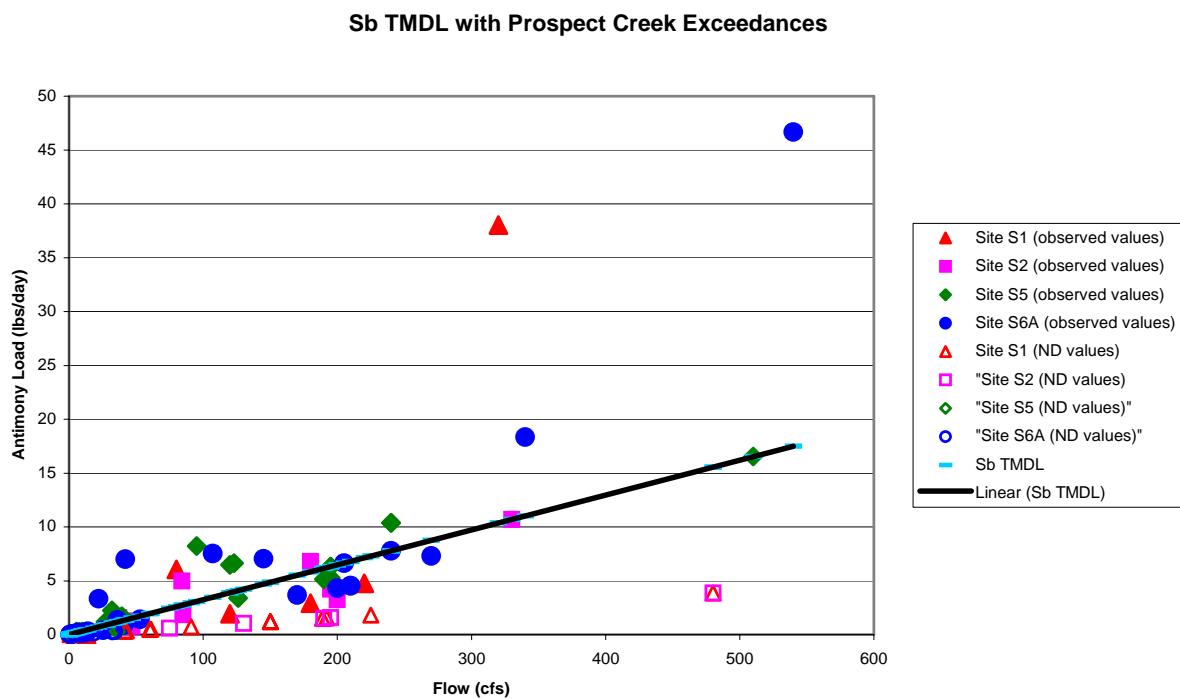


Figure E-4. Sb TMDL with Prospect Creek Exceedances.

Table E-2. Prospect Creek High and Low Flow Monitoring Data.

| | High Flow Monitoring Dates | | | 4/26/00 | | | 6/29/00 | | |
|------|----------------------------|---------------|-------------------|------------|---------------|-------------------|------------|---------------|-------------------|
| | 6/25/99 | | | 4/26/00 | | | 6/29/00 | | |
| Site | Flow (cfs) | Concentration | Sb Load (lbs/day) | Flow (cfs) | Concentration | Sb Load (lbs/day) | Flow (cfs) | Concentration | Sb Load (lbs/day) |
| S-1 | 320 | 22 | 38.02 | 225 | <3 | <3.645 | 150 | <3 | <2.43 |
| S-2 | 330 | 6 | 10.69 | 200 | 3 | 3.24 | 75 | <3 | <1.21 |
| S-11 | .95 | 7 | .0359 | 6 | <3 | <.0972 | 1.3 | 6 | .0421 |
| S-5 | 240 | 8 | 10.37 | 240 | 8 | 10.37 | 123 | 10 | 6.63 |
| S-6A | 340 | 10 | 18.36 | 270 | 5 | 7.29 | 145 | 9 | 7.04 |

Table E-2. Prospect Creek High and Low Flow Monitoring Data.

| | 5/9/02 | | | 4/23/03 | | |
|----------------------------------|-----------------|-------------------|----------------------|----------------|---------------|----------------------|
| S-1 | 120 | 3 | 1.94 | 220 | 4 | 4.75 |
| S-2 | 85 | 4 | 1.83 | 190 | <3 | <3.07 |
| S-11 | 35 | 15 | 2.83 | 3.6 | <3 | <0.058 |
| S-5 | 120 | 10 | 6.47 | 195 | 6 | 6.31 |
| S-6A | 205 | 6 | 6.63 | 200 | 4 | 4.32 |
| Low Flow Monitoring Dates | | | | | | |
| | 11/12/99 | | | 9/29/00 | | |
| Site | Flow (cfs) | Concentrati on | Sb Load (lbs/day) | Flow (cfs) | Concentration | Sb Load (lbs/day) |
| S-1 | 9.6 | 3 | .155 | Dry | ND | NC |
| S-2 | Dry | ND | NC | Dry | ND | NC |
| S-11 | .002 | <3 | <0.00003 | .004 | <3 | .00006 |
| S-5 | 10 | 5 | .27 | .9 | 4 | .019 |
| S-6A | 14 | 4 | .302 | 1.1 | 4 | .024 |
| | 8/29/02 | | | 6/29/03 | | |
| S-1 | Dry | ND | NC | 41.6 | <3 | .6731 |
| S-2 | ND | ND | ND | Dry | ND | NC |
| S-11 | .002 | 4 | .00004 | .017 | <3 | .0003 |
| S-5 | 11 | 3 | .178 | 36 | <3 | .583 |
| S-6A | 22 | 28 | 3.32 | 34 | <3 | .55 |

NOTES: *Reported value, probably an error.

ND = no data.

NC = not calculated.

Bold values indicate antimony concentrations exceeded water quality criteria for the given location.

- The upper Prospect Creek monitoring site (S-1), which is located between Antimony Creek and Cox Gulch (Figure 3-1), typically shows antimony loads that are at least one and sometimes several orders of magnitude greater than the estimated loads from the east and west forks of Antimony Creek, under both high and low flow conditions (Table E-1). Therefore, one or more additional sources of metals loading are indicated upstream of the S-1 monitoring site. The additional loading source(s) may be located in lower Antimony Creek or in Prospect Creek drainage upstream and/or downstream of the confluence with Antimony Creek (Figure 3-1). The potential for these existing sources within the upper portions of the Prospect Creek drainage and within tributary drainages such as Cooper Creek is supported by the existence of abandoned/inactive mines, as shown in Figure (3-1).
- Prospect Creek between sites S-1 and S-2 often goes dry over several sections where the flow is subsurface for large distances during part of the year, making evaluation of loading trends difficult in this reach. However, available data (Table 3-5) show that antimony loads typically remain constant or decrease over this reach. The decrease in load could be completely due to the fact that much of the flow goes subsurface along with the corresponding antimony load since antimony concentrations tend to remain

constant in this reach. Therefore, no apparent loading sources have been identified between sites S-1 and S-2.

- Prospect Creek between sites S-2 and S-5 generally shows an increase in antimony loading during high flow conditions; low flow conditions could not be evaluated due to predominantly dry conditions at site S-2 (Table 3-5). Potential metals sources in this reach of Prospect Creek include tributary drainages (including Cox Gulch), mining-related sources along the Prospect Creek floodplain, recharge from mineralized ground water (either natural or mining-related), or instream sources related to remobilization of previously precipitated metals.
- Between sites S-5 and S-6A on Prospect Creek, loads typically remain constant under both high and low flow conditions. However, during two of the monitoring events reviewed (June 1999 high flow and August 2002 low flow), loading increases were noted between these two locations (Table 3-5). Potential sources of the apparent load increase in this reach of Prospect Creek include ground water (alluvial or bedrock), floodplain or instream sources, two relatively large tributary drainages (Crow Creek and Therriault Creek), and one or more smaller tributary drainages that join Prospect Creek between S-5 and S-6A (Figure 3-1).

These trends in antimony loading for Antimony Creek, Cox Gulch, and Prospect Creek, are used to support TMDL development and load allocations in Section 4.0. It should be noted that the loading trends and potential source assessment have been completed using existing water quality data only. A more complete assessment of specific loading sources would require additional monitoring within the watershed, as discussed in Section 5.0.